OMCLDRR README FILE

Overview

This document presents a brief description of the OMCLDRR data product. OMCLDRR contains effective cloud pressures and fraction along with ancillary information generated using the OMI global mode measurements. In this mode, each file contains the pole-to-pole sunlit portion of a single orbit that is 2600 km wide in the cross-track direction and consists of 60 ground pixels across the track. OMCLDRR retrieves cloud pressures from an amount of filling in of solar Fraunhofer lines caused by rotational-Raman (RR) scattering in the atmosphere.

You may refer to Release Specific Information about OMCLDRR for details about software versions and known problems.

Algorithm Description and Validation

For a description of the algorithm used in deriving OMCLDRR please refer to the Algorithm Theoretical Basis Document (ATBD) on http://eospso.gsfc.nasa.gov/eos_homepage/for_scientists/atbd/viewInstrument.php?instrument=13, which also contains other algorithm related documents. There are several journal papers related to the most recent algorithm updates and validation. These include *Joiner et al*. (2004), *Vasilkov et al.* (2004), *Joiner and Vasilkov* (2006), and *Vasilkov et al.* (2008). *Joiner and Vasilkov* (2006) contains a description of a soft-calibration procedure that is used to remove scan position-dependent biases (*i.e.* striping) from the retrieved cloud pressures. *Vasilkov et al.* (2008) and *Joiner et al.* (2011) contain detailed error analyses and validation using CloudSat/MODIS 2B-TAU optical extinction profiles. This algorithm is one of the two algorithms that derive cloud information from OMI data. The other algorithm uses O_2-O_2

absorption near 477 nm and its product is named OMCLDO2. Comparisons between the two products are given in *Sneep et al*. (2008) (older version of OMCLDRR) and *Joiner et al*. (2011).

Data Quality Assessment and Uncertainties

Users should be aware that both the OMCLDRR cloud pressure and fraction are *effective*, meaning that the cloud fraction does not represent true geometrical cloud fraction. The cloud pressure does not represent the physical cloud-top pressure (especially in the case of multiple cloud layers), but rather a reflectance-weighted cloud pressure that we now call the cloud Optical Centroid Pressure (OCP). A fast simulator to produce estimates of cloud OCP based on profiles of cloud extinction has been developed (see *Joiner et al*., 2011). An IDL version of the fast simulator is available upon request (see algorithm contact information below).

It is not possible to derive a sub-pixel geometrical cloud fraction using OMI radiances. The effective cloud fraction is based on assumptions about the cloud and ground reflectivities (see *Stammes et al*., 2008 for an overview). The effective cloud fraction is intended for use in conjunction with the effective cloud pressure such that the combination of the two produces the amount of observed Raman scattering (or atmospheric absorption).

The cloud pressures are representative of pressure levels reached by back-scattered photons averaged over a weighting function. The fast simulator of *Joiner et al.* (2011) provides an estimate of this weighting function. The algorithm uses the concept of the mixed Lambertian-equivalent reflectivity (MLER) in which a surface (cloud or ground) is assumed opaque and Lambertian. In the MLER model, a cloud fraction is used to weight the radiances coming from the clear and cloudy portions of the pixel. In our algorithm, an effective cloud fraction is computed using assumptions about the cloud and ground reflectivities as will be described below. Scattering and/or absorption from within and below a cloud or between multiple cloud decks can be accounted for because effective cloud fractions are lower than geometrical cloud fractions and cloud OCPs are typically higher (altitudes lower) than cloud-top pressure derived from thermal infrared measurements and cloud lidars.

The cloud radiance fraction (derived at 354.1 nm) is also provided in the OMCLDRR files. This quantity is defined at each pixel as the fraction of the measured radiance that is scattered by clouds, i.e., the effective cloud fraction times the assumed cloudy radiance divided by the measured radiance. Because the measured radiance is wavelength dependent due to surface albedo and Rayleigh scattering, the cloud radiance fraction is also wavelength dependent.

OMCLDRR products, particularly the cloud OCP, are very sensitive to the so-called row anomaly, presumably caused by an obstruction outside the instrument that causes scattered Earthshine and sunshine into the instrument for certain swath positions after June 2007. Please consult http://disc.sci.gsfc.nasa.gov/Aura/data-holdings/OMI/index.shtml - info for the latest information. It is recommended to use the OMTO3 flagging scheme (to be released early 2012) for detection and removal of affected rows. Information on the level 1 B flagging scheme is contained in the field "XTrackQualityFlags" for convenience.

Comparisons between OMCLDRR and OMCLDO2 cloud OCPs show good agreement; mean differences are 40 hPa (OMCLDO2 having higher pressures on average) over land and 25 hPa over ocean and standard deviations are approximately 63 hPa over both land and ocean for effective cloud fractions > 0.75 (*Joiner et al.*, 2011). Because these retrievals are based on different physical principles and use different OMI detectors, but are made from the same instrument, we believe that this comparison provides upper limits on the estimated accuracies and precision for the stated conditions. Precision decreases with effective cloud fraction or more precisely with the cloud radiance fraction (CRF). It can be shown that, neglecting errors in the computed clear sky radiance, the precision should be proportional to 1/CRF. Based on the work of *Joiner et al.* (2011) we find that indeed, the standard deviation of cloud OCP increases by approximately the expected amount for effective cloud fractions between 0.5 and 0.75. If the precisions of OMCLDRR and OMCLDO2 are comparable, then the precision of OMCLDRR for cloud radiance fractions near unity should be approximately 44 hPa. This leads to estimated precisions of approximately 59, 88, and 176 hPa for CRF values of 0.75, 0.5, and 0.25, respectively. Note that errors increase rapidly for the lowest effective cloud fractions. For example, at CRF=0.1, which corresponds to an effective cloud fraction of 0.05, errors would be approximately 440 hPa. This is why cloud OCP is not retrieved for effective cloud fractions < 0.05.

Algorithm Features and Updates:

1) In version 1.0 of OMCLDRR, we used the spectral range 392-398 nm. We found that this fitting window had some undesirable features including 1) Sensitivity to Raman scattering in the ocean 2) Sensitivity to non-Lambertian behavior of clouds and ground including cloud shadowing, thin cloud phase function, non-Lambertian behavior of the surface (*e.g.* sea glint) 3) Sensitivity to instrument stray light. In version 1.1 and beyond, we use the fitting window 346-354 nm. There is significantly more Rayleigh scattering at these wavelengths that mitigates (but does not completely eliminate) problems associated with all of the features mentioned above. Due to the change in fitting window, OMCLDRR now uses the UV-2 channel to derive cloud pressure, cloud fraction, and reflectivity. This has an added benefit that the cloud fields will have slightly better co-

registration with other OMI products (ozone, BrO, and HCHO) that use the UV-2 channel.

2) Under low cloud fraction conditions (<~0.3), sea glint (and other non-Lambertian surface features) can produce high values of retrieved reflectivity and low values of cloud pressure. Sea glint primarily affects the West side of swath at low and mid-latitudes. The sea glint possibility flag is contained in bit 4 of the ground pixel quality flag. As mentioned above, cloud pressures are much improved in v1.1 over sea glint conditions. Versions 1.8 and higher use a new model for ocean surface reflectivity based on the Cox-Munk scheme and climatological estimates of water leaving radiance based on TOMS data. This model flattened out the cross-track dependence of the effective cloud fraction.

3) Over snow/ice, the processing quality flag bit 5 is set to 1, and the cloud fraction is assigned to 1. Therefore, the effective cloud pressure for these pixels is represents an average scene pressure (*i.e*. the LER pressure of a pixel that produces the observed amount of Raman scattering). This is done in order to more positively identify the existence of thick clouds over snow/ice (see *Vasilkov et al*., 2010 for a detailed discussion). This is of interest for the retrieval of ozone and other trace gases as well as the calculation of surface UVB. The snow/ice information comes from the Near real-time Ice and Snow Extent (NISE) product created using passive microwave data. It is provided by the National Snow and Ice Data Center (NSIDC) and is included in the level 1b data set.

4) As the cloud radiance fraction tends to zero, the error in retrieved cloud pressure increases rapidly. These errors can be seen in some cases where cloud fractions are very low (20% or less). For effective cloud fractions < 5%, we do not

attempt a cloud pressure retrieval. Instead, an effective scene pressure is reported for diagnostic purposes only. These cases are indicated where bit 13 of the processing quality flag is set to 1. Retrievals for effective cloud fractions < 20% should be used with caution.

5) Transient events due to radiation hits on a detector may produce striping in the cloud pressures (*e.g.* anomalously low or high values at one scan position). This may last only for a short period or may continue until elevated dark currents are corrected for in the calibration (these adjustments are made daily in collection 3). Transient data are currently flagged in the level 1b data set. OMCLDRR has the option of checking this flag. However, the default is currently not to check the flag. When the transient flag is checked, the algorithm disregards affected transient pixels as well as pixels affected by other types of error within the fitting window. In practice, we found that the transient flags are set very infrequently and our internal quality control checks are able to detect affected pixels most of the time. When any type of warning or error occurs for pixels within the fitting window for radiance or irradiances, bits 9-12 of the processing quality flag are set as appropriate.

6) Absorbing aerosol in and above clouds can affect the OMCLDRR data. In general, it will reduce cloud fractions and pressures. The presence of absorbing aerosols is currently not flagged in the OMCLDRR file. The aerosol index flag in the OMTO3 file can be used to check for the existence of absorbing aerosol within a pixel.

7) Versions 1.4 and higher use a monthly surface albedo climatology over land based on TOMS data. Previous versions assumed a surface reflectivity of 15% consistent with OMTO3. With this change and additional changes in the

instrument calibration in collection 3, we find the cloud pressures to be higher on average than in previous versions, particularly at low cloud fractions and more consistent with OMCLDO2.

8) Cloud fractions and subsequently the cloud pressures are sensitive to the instrument calibration and any calibration drift. Until the instrument calibration has been fully characterized as a function of time, users are cautioned not to use these products for deriving long-term trends.

9) Version 1.9 updates the soft-calibration yearly. Analysis of the data showed increased striping over time and a drift in the derived surface pressure over Antarctica. The cause of this drift is currently under investigation. The use of time-dependent soft-calibration reduces striping and lessens artificial trends in the cloud pressures. However, the soft-calibration is designed to remove multiplicative errors. There are indications that additive errors contribute to the trends in OMCLDRR cloud pressures. Our soft calibration will not be able to fully remove additive errors. We also note that there are also small trends in absolute calibration (at the few percent level or less). We have not made any adjustments to account for these trends that affect both the effective cloud fraction and pressure.

Product Description

A 2600 km wide OMI scan contains 60 pixels. Due to small asymmetries between the instrument optic axis with the spacecraft nadir, the pixels on the swath are not symmetrically aligned on the line perpendicular to the orbital plane. However, the latitude and longitude provided with each pixel represent the location of each pixel on the ground to a fraction of a pixel. The OMI pixel corner product (OMPIXCOR) may be used to accurately map or define the pixel edges.

The OMCLDRR product is written as an HDF-EOS5 swath file. For a list of tools that read HDF-EOS5 data files, please visit this link: http://disc.gsfc.nasa.gov/Aura/tools.shtml.

An OMCLDRR file, also called a granule, contains effective cloud pressures and fractions. The relevant cloud products are called CloudPressureforO3 and CloudFractionforO3, respectively.

The output file also contains associated information retrieved from each OMI pixel from the sun-lit portion of an Aura orbit. The data are ordered in time sequence. The information provided on these files includes: Latitude, longitude, solar zenith angle, satellite zenith angle, relative azimuth angle, reflectivity at 356.5 nm and a large number of ancillary parameters that provide information to assess data quality. By far the most important of these parameters is the processing quality flag. Most users should accept cloud pressure data where the processing quality flag bits 0,1,2,3,4,6,7,13,14,15 are set to zero. In addition, data with bit 5 set to 1 should be used with caution, as these are data over snow/ice where the cloud fraction has been set to unity and the model reverts to the Lambertian-equivalent reflectivity model (LER) rather than the MLER. A cloud mask is provided in the data set but should not be used, as its quality has not yet been assessed. For effective cloud fractions, data are valid with processing quality flag bits 2, 3, and 13 set to unity.

For a complete list of the parameters and bit settings for quality control flags, please read the OMCLDRR file specification document. In addition, the OMCLDRRG data sets makes OMCLDRR data available in a geographically-ordered (rather than time-ordered) format that can be more easily subsetted and manipulated. Please check the Goddard Earth Sciences (GES)

Distributed Active Archive Center (DAAC) website for current information on these products where the usual standard time-ordered level 2 products can also be found.

Full OMCLDRR data, as well as subsets of these data over many ground stations and along Aura validation aircraft flights paths are also available through the Aura Validation Data Center (AVDC) website to those investigators who are associated with the various Aura science teams.

Questions related to the OMCLDRR dataset should be directed to the GES DAAC.
Users interested in this product or with questions regarding the OMCLDRR dataset are advised to contact Alexander Vasilkov (alexander_vassilkov@ssaihq.com) and/or Joanna Joiner (Joanna.Joiner@nasa.gov), who have the overall responsibility for this product.

References

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